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THE PURIFICATION OF SEWAGE BY BACTERIAL OXIDATION

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THE PURIFICATION OF SEWAGE

BY BACTERIAL OXIDATION.

A STUDY OF THE NATURAL PROCESSES OF FILTH REMOVAL
AND OF THE MEANS BY WHICH THEIR EFFICIENCY
MAY BE ARTIFICIALLY INTENSIFIED.

INCLUDING A DESCRIPTION OF WORKS FOR SEWAGE DISPOSAL
AT WILLOW GROVE PARK, PHILADELPHIA, PA.

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BY GEO. E. WARING, JR.,
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OBSERVER PRINT, CHARLOTTE, N. C.

SEWAGE DISPOSAL PLANTS.

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THE PURIFICATION OF SEWAGE BY BACTERIAL OXIDATION.

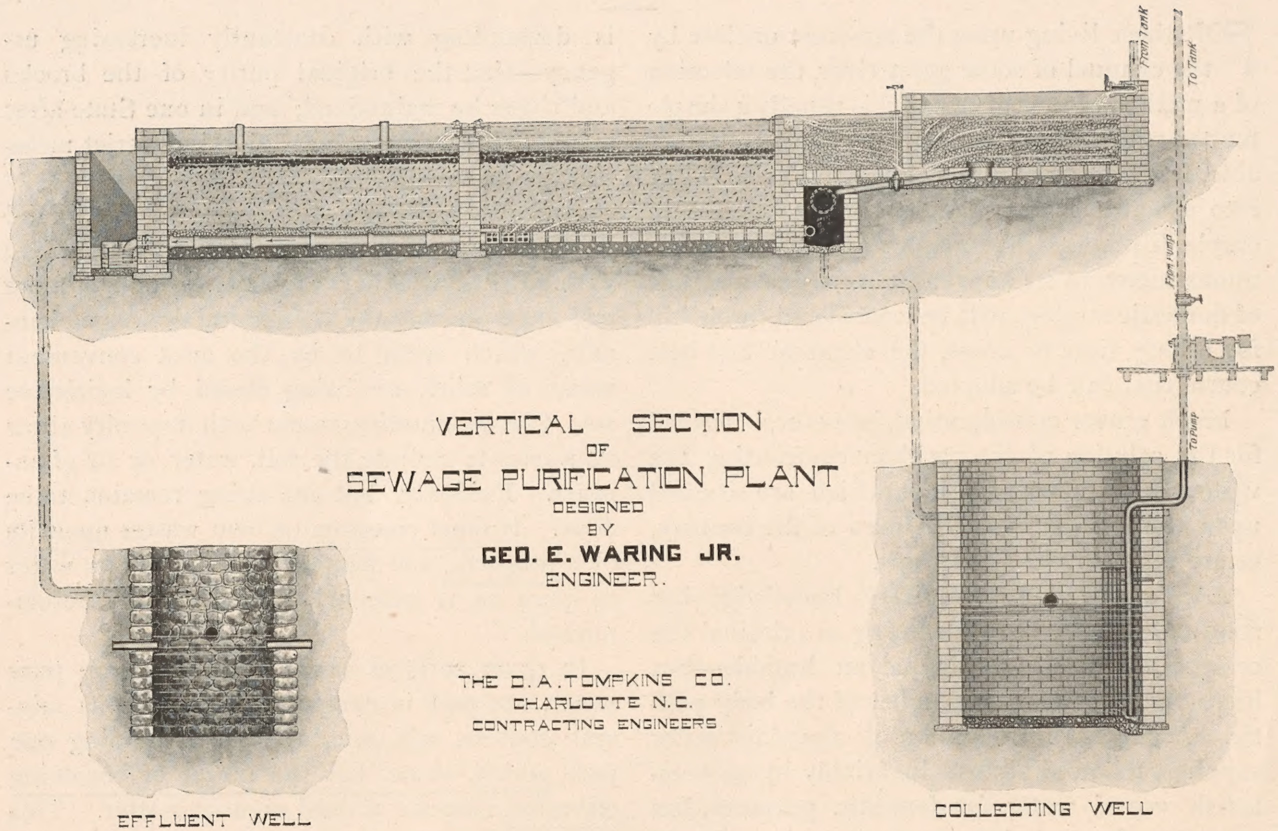
FOR those living upon the sea-coast or close by the channel of some great river, the selection of a method of sewage disposal is usually a simple matter. Where the natural conditions are favorable, free discharge into a strong tidal current or into a water course sufficient in size to insure ample dilution, swift enough to prevent deposits, unobstructed in its flow and not used as a source of domestic supply, will be considered, probably for a long time to come, the cheapest and best course that can be adopted.

Much graver consideration, however, is needed for the solution of the problem confronting the vast number of communities which are situated upon the smaller water courses of the country, or are remote from all streams.

A wider diffusion of sanitary knowledge has resulted, rightly, in condemning as criminal the cesspool, formerly considered an humble—but honest and necessary—member of the body politic. A general introduction of abundant water supplies, followed almost invariably by an over-lavish use of water for domestic purposes, has created a demand for sewers to remove liquid wastes. These sewers must have an outlet. Awakened public sentiment has demanded—and is demanding with constantly increasing urgency—that the original purity of the brooks and rivers be maintained; and in one State after another, Legislatures are adopting strict measures to secure this end.

As a result, the great majority of the inland cities and towns are being brought face to face with conditions which are daily becoming more and more serious, and the natural drainage channels, which seem to be the most convenient means of relief, are being closed by legislative act. One community cannot with impunity allow its wastes to pollute the soil, water or air of another. Evidently but one thing remains to be done. It must consume its own wastes upon its own property, and pass on to its neighbors water as pure as it received. This can be accomplished.

In 1,000 parts of sewage 998 parts are pure water, one part is composed of innocuous mineral matters, salt, etc., and the remaining one part, which, alone, has the power of becoming offensive, consists of dead organic matter. This matter is complex in structure, but the materials of which it is built are simple mineral substances, which have been appropriated for a time by a



VERTICAL SECTION
OF
SEWAGE PURIFICATION PLANT
DESIGNED
BY
GEO. E. WARING JR.
ENGINEER.

THE D. A. TOMPKINS CO.
CHARLOTTE N. C.
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PLATE I.

DESCRIPTION OF PLATE I.

A detailed description of this Plate will be found on page 14 and following.

The two small elevated beds on the right are the "strainers" in which the solid matter is caught and consumed. The sewage may be supplied by direct gravity flow, or pumped from a collecting well direct or through an overhead tank as conditions may require.

The two left hand beds are for the destruction of the soluble organic matter, so that the final effluent is no longer sewage but pure and drinkable water. Not only is it in *appearance* as clear and sparkling as a mountain spring, but it is in *fact* free from organic or noxious chemical contamination and of a standard of purity better than the average water supply in which it originated.

In the Plate, the effluent is shown as leeching away into the soil; but it is frequently used for street sprinkling, landscape decoration, in pools, fountains, brooks, cascades, etc., etc. But for the sentiment attaching to it, it might be used with impunity for any domestic or mechanical purpose.

The chamber shown in solid black serves the double purpose of an air channel communicating with all the beds, and a drainage vault through which the strainers, when periodically emptied, return their contents into the collecting well.

living plant or animal, and which, having served a term of usefulness, are rejected. Their ultimate destiny is disintegration and the return of their elements to the mineral world, to begin again, when occasion offers, the cycle of life, death and decay. This disintegration is as important in the economy of nature as are the processes of life. Without it, the organic world would soon lie buried in its own filth, and the supply of plant food would become exhausted. The materials needed for the growth of organic structures are loaned, not given; and when the building ceases to be useful, it must be torn down and its materials must be returned to the common store-house.

This process of demolition can be effected only by oxidation. A complete result could be attained, theoretically, by the application of fire, which is simply rapid chemical oxidation; but it is obvious that the purification of sewage by this means is impracticable. Nature accomplishes the same complete result by a biological combustion. In this process, the reducing agents are minute living organisms, which tear apart the complex products of life, and combine the elemental carbon, hydrogen and nitrogen with the oxygen of the air, forming carbonic acid, water and nitrous and nitric acids.

Bacterial disintegration may be accomplished, broadly speaking, in either of two ways;—by decomposition or by putrefaction. (There are many intermediate forms of change, which merge one into the other, so that a sharp line of division between these processes is impossible.) Both accomplish the same final result—the resolution of organic tissues into their component elements. This end is reached by progressive changes. In decomposition these changes are inoffensive and innocuous; in putrefaction the intermediate products are disgusting and possibly dangerous. This distinction must be kept clearly in mind.

The essential difference between these processes is that, in the former, the reducing bacteria are of a kind which require for effective work the presence of abundant air, while in the latter little or no air is needed for the operations of its agents. As organic structure breaks down under decomposition, its constituents combine with atmospheric oxygen to form carbonic acid, water and innocuous mineral salts. As similar matter is disintegrated by putrefaction, the elements, set free in the absence of air, recombine and form offensive compounds, some of which are poisonous. It is the latter process which produces disgusting, and probably dangerous, con-

ditions in sewage which has been stored in mass, as in a cesspool.

But decay in one of the two forms is inevitable. The sooner it is accomplished, and the more direct the manner, the better will be the result. We can delay it—we can postpone the end for a considerable time—but we cannot alter the final outcome. We can treat sewage with disinfectants which will stop the work of disintegration, but it will commence again as soon as the antiseptic agent is weakened by dilution, evaporation or other cause. Such treatment results only in shifting the scene of the decay. It simply transfers the possible evil from the present to the future—from our own territory to that of our neighbors.

A far wiser course is not to retard but to hasten the natural processes of decomposition (using always the word in its literal scientific meaning, namely—resolution into the original component mineral and gaseous elements) by providing conditions most favorable to the complete and rapid breaking up of the organic structure. Bacterial oxidation, when properly controlled, insures complete freedom from offence and danger. It can be made to produce any necessary degree of purification; for, not only are the solid impurities of sewage removed by the energetic scavenger bacteria, but even the filth which is in solution is attacked and destroyed, under favorable conditions, so that the water of the foulest sewer can be made as pure as that of the mountain brook.

To accomplish this natural purification, it is only necessary to bring the sewage into contact with light, well-ærated soil. The reducing bacteria always abound in the sewage itself, in the surface soil and in the air, and oxygen, the only other essential, is freely supplied by the atmosphere. When sewage is spread over a natural surface, it is important that it be applied in thin sheets and intermittently, so that every particle of the liquid and of the soil may come in contact with air. This is the process known as "Broad Irrigation." It has been used so widely, and with such signal success, that further description is unnecessary. Where abundant land is available, it is the system *par excellence* for sewage treatment. Its application, however, necessitates the purchase and preparation of considerable ground. The land must be sufficiently well drained, naturally or artificially, to afford free escape for the descending water, and carefully graded so that the distribution of the sewage may be uniform. Under good management, one acre will purify the

PLATE II.

DESCRIPTION OF PLATE II.

This plant is erected in Willow Grove Park, owned by the Union Traction Co., of Philadelphia. The large building with the stack is the Terminal Power House of the Company. The Sewage Disposal Plant is seen in the foreground, being only about two hundred yards from the main entrance to the Park. One of the park drive-ways, with a distant hint of the grounds, pavilions, etc., is seen at the right of the picture.

The oval stone building supporting the tanks serves also as the local power house containing the motor, pump and blower.

Just off the limits of the picture at the right is a large ornamental lake surrounded with lawns and summer houses, decorated with aquatic plants, illuminated at night by an electric fountain and covered with pleasure craft of all kinds. It would be hard to convince the observer, in the face of the notable and obvious purity of the water, that this lake is practically the recovered sewage of the Park ;—but such is nevertheless the fact.

wastes of from five hundred to one thousand persons.

Where sufficient land, suitable for irrigation, is not avilable, "Intermittent Downward Filtration" is sometimes used. This is not a different process, but only the same process intensified one step; for the purifying agents and the necessary conditions are the same, namely;—reducing bacteria and abundant æration. In it, the purification is effected, not only on the surface of the soil, but also under the surface; for in a properly constructed filter-bed, the material is so porous that, as the applied sewage sinks away, the air which follows it can penetrate the mass and make bacterial oxidation possible at a considerable depth. By thus extending downward the zone of bacterial activity, the capacity of a given area is much increased; for the purification depends upon the exposure of the sewage, for a certain length of time, to the action of the oxidizing organisms; and it is obvious that, without reducing this period of exposure, sewage can be passed more rapidly through a deep layer of purifying material than through the shallow layer upon which the process of irrigation depends.

Intermittent application of the sewage is necessary, in order that the water may drain away and air enter the pores of the soil. While one area is undergoing æration, the flow must be diverted to other tracts, which, after use, must be ærated in like manner.

Under this process, one acre of beds will purify the sewage of from fifteen hundred to three thousand people. That its capacity is thus limited is owing, not to the great amount of impurity which is contained in the sewage, but, principally, to the length of time required for the penetration of the filtering material by the air. Absorbtion from the atmosphere is, necessarily, a slow process, and until air has reached the innermost recesses where organic matter is stored, the purifying process in these places cannot begin. The amount of oxygen available for nitrification is, moreover, limited; for, when once the pores of the soil have filled with air, the underground atmospheric circulation is so slight that fresh oxygen is not supplied to take the place of that which has been used, and the gaseous products of the decomposition are not carried away, but remain to hinder to a constantly increasing extent the purification which is taking place.

In 1891 it occurred to the writer that the capacity of a filter-bed might be increased by supplying artificially the air needed for the stimula-

tion and sustenance of bacterial action. It seemed probable that the use of air under pressure would not only insure the introduction of oxygen to every part of the filter, but would make it possible to change its gaseous contents as often as might be found desirable.

To determine the value of this theory, an experimental plant, on a practical working scale, was erected and put in operation, at Newport, R. I., in 1894. In outline the double process consisted, first, of the mechanical deposition in filter-beds of all solid matters carried in suspension in sewage, and their subsequent destruction by forced æration;—and second, the further and complete purification of the clarified sewage by bacterial oxidation of its dissolved impurities in an artificially ærated filter.

The details of the construction and operation of this plant have already been published.* It is sufficient for the purpose of this paper to say that the results accomplished exceeded the most sanguine expectations. It was found that one acre of artificially ærated filters would purify the wastes of from ten thousand to twenty thousand people.

The sewage used (pumped from the main outfall sewer of the city) contained not only the fresh wastes normally present, but the putrid overflow of many old cesspools; yet the liquid leaving the tanks was clear, white, odorless and tasteless. It was collected in a large tank where discoloration would have been at once apparent, and in this tank fish lived and thrived. Engineers and committee-men drank of it freely and pronounced it good, and frequent chemical analyses proved it actually pure—a good drinking water. An average of the figures representing the purification accomplished showed that 92.5 per cent. of the organic matter was removed. At one time a removal of 99.08 per cent. was effected. As the total organic impurity originally in the sewage was but $\frac{1}{1000}$th part of the whole mass, this degree of purification means that the water escaping from the filters contained but .0000092 part of objectionable material.

This complete regeneration continued through five months until the experiment was concluded. The filtering material was never renewed, yet when the tanks were taken apart it was found to be as clean and sweet as beach-washed gravel. There was absolutely no suggestion of the

*"The Purification of Sewage by Forced Æration," which can be obtained in pamphlet form on application to the writer at Newport, R. I., or to The D. A. Tompkins Company, Charlotte, N. C.

PLATE III.

DESCRIPTION OF PLATE III.

The left of the two tanks receives the crude sewage pumped from the collecting well, and serves as a distributing reservoir for the night run when the plant is without an attendant. The right hand tank receives the purified sewage from the effluent well when it is to be stored for delivery to the sprinkling carts. Not only is the entire system of pleasure drive-ways throughout the Park sprinkled daily in the summer with the effluent, but also the city avenues for a mile in every direction through a choice suburban residence district. A hint of the character of these residences can be seen in the background, many of them being within a few hundred yards of the plant itself.

Remembering the arbitrary and jealous powers granted to a City Board of Health, and setting aside all strictly scientific testimony, the constant daily use of the recovered sewage not only in a public pleasure lake, but under the still severer test of street sprinkling in summer weather, is the most practical and conclusive evidence to the layman of the absolute completeness of the process.

hundreds of thousands of gallons of sewage which had passed through it. The filth had completely disappeared. It had been broken up into harmless mineral elements, some of which had escaped into the air, while the rest passed out with the effluent water.

At the close of the experiment the plant was moved to Providence, enlarged and installed in the yard of the Silver Springs Bleaching and Dyeing Company, to purify for dyeing purposes the water of West River, a small stream much polluted by the wastes of a large woolen mill upon its banks a short distance above the bleaching works. The results of this use have been entirely satisfactory, and a series of comparative tests in dyeing certain very delicate shades indicates that the filter effluent is fully as good as distilled water for this purpose.

Early in the spring of 1897 the writer was called upon to advise concerning a serious problem of sewage disposal at Willow Grove Park, Penna. This is a popular pleasure-ground, of one hundred and ten acres, lying in a basin at the foot of the Chelten Hills, fifteen miles north of Philadelphia, on the old York Road. It is owned and controlled by the Union Traction Company, of Philadelphia, whose directors have done all that genius and money could accomplish to make the spot attractive. The Park was opened in 1896, and vast crowds of people visited it. It soon became apparent that there was grave need of suitable means of sewage disposal. Lavatories and toilet rooms lay scattered in all parts of the grounds; a large restaurant poured forth a volume of liquid waste; dairies and ice cream pavilions furnished contributions of wash-water, and the sewage from the car-barn and employees' quarters (Willow Grove is a terminal) added considerably to the flow. The liquid is somewhat less dilute than ordinary town sewage, for no laundry or bath wastes enter the system. The total amount is estimated as 80,000 to 100,000 gallons per day.

The only water-course in the neighborhood is a stream that runs through the grounds, feeding an artificial lake and lily ponds. At times, in summer—unfortunately when the flow of sewage is greatest—this stream is dry, and at no season of the year is it sufficiently large to warrant the discharge of sewage into it. Its average flow would pass through a four-inch pipe. Furthermore it is dammed a short distance below the Park to make a lake for boating in another garden resort.

Under these circumstances, some method of artificial treatment was necessary. The only

land available for irrigation was a tract nearly a mile away and considerably above the level of the Park. To reach it involved the laying of a long force-main and heavy pumping. The soil of the surrounding country is a deep bed of stiff clay, not suitable in its natural condition for disposal by irrigation, and absolutely unfit for intermittent filtration. The use of the latter process would have necessitated the artificial construction of the entire set of filter beds, covering about one acre, with material brought from a distance.

The system of filtration with forced æration, which required about one-eighth of this area, was, therefore, adopted. Plans were completed in March, and the work of construction began early in April. The plant is located on the Union Traction Company's property, just outside of the trolley-road which encircles the Park, and close beside the railway power-house.

As the sewage cannot reach the filters by gravity flow, it is collected in a receiving well (under the pump and tank house shown in Plate), which has a storage capacity of about 12,000 gallons. The essential feature of this well as related to the filters is its system of screens, designed to withhold such substances as rags, paper, corks, lemon-skins, etc., which are inoffensive in themselves and which would encumber the filter-beds needlessly. These screens also serve to detain the coarser putrescible matters until they are so softened and broken up as to pass the mesh. A finely divided condition favors their ultimate destruction in the filters. Two screens are used. The first and outside of these is formed of 5/8 inch vertical iron rods, half an inch apart, and is fastened permanently in place across the entrance to the chamber surrounding the suction pipe which empties the well. The inner screen is a frame of flat iron, well braced, covered with galvanized iron netting of 1/4 inch mesh. It slides into grooves of channel-iron built into the walls of the chamber, so that it can be lifted out for such occasional cleansing as may be necessary. A second pair of grooves, close to the first, is provided to receive a duplicate screen which is lowered into place before the fouled one is removed. It has been found, in practice, that one of these fine screens will pass sewage for six or eight weeks without clogging.

From this well the sewage is pumped to a distributing-tank upon the roof of the building and directly over the well. A small centrifugal pump was originally installed for this work, and, save for a little occasional difficulty in priming, its service was satisfactory. Later, for reasons which concerned the policy of the power-house

PLATE IV.

DESCRIPTION OF PLATE IV.

This view is looking from the stone power house out over the beds. The six beds in the background are the "strainers" in three sections of two compartments each. The middle section is now in service. The crude sewage is flowing in from the two gates at the rear wall, passing down underneath the middle diaphragm wall, coming up through the nearer bed and from thence being distributed by channels and pipes over the four beds in the foreground which are the "ærating beds." The flow to these beds is controlled by the four valves shown at the intersection of the cross walls in the foreground. The vent tiles for the air discharge are seen projecting up through the blanket of sand on the ærating beds. No odor whatever is perceptible to the casual visitor, but if the air issuing from the vents is closely inhaled, a faint but fresh and agreeable earthy odor can be detected, resembling almost exactly that perceived in a green house. In fact, the filters are neither more nor less than a green house containing an active vegetable growth of microscopic plants feeding upon and disintegrating the rich soil supplied to them.

management, and which had no connection with its efficiency, a steam piston pump was substituted for the electric centrifugal. A fan blower supplying air to the filters has always been driven by an electric motor, fed from the trolley current.

From an outlet in the bottom of the distributing tank, the sewage runs by gravity to the filter-beds. The rate of flow is controlled by a valve under the tank, and this is adjusted so that, under normal conditions, the sewage will accumulate gradually in the tank during the day, to escape at night when the amount of incoming sewage is greatly reduced. In this way a more or less constant flow is maintained throughout the twenty-four hours.

The filtering material is contained in shallow rectanglar beds, with walls of masonry and concrete floors. Over each floor extends a system of channels (made of hollow Raritan tile, laid loosely, with open joints) which collect the water and lead it to its outlet, and which also serve to distribute throughout the filter the air furnished by the blower.

The process of purification comprises two distinct operations, one withholding and destroying all the organic matters carried in suspension in the sewage, and the other removing the impurities in solution. The same change—bacterial oxidation—takes place in both operations. It is simply more convenient, for mechanical reasons, to allow the flow to pass through two filters, each especially designed for its peculiar work, than to carry on complete purification in one filter.

The first of these filter beds, called the "strainer," is divided into two compartments by a diaphragm wall, which does not rise from the floor but is built upon the false flooring of hollow tile, so that liquid and air can pass freely under it from one compartment to the other. Each bed is filled with broken stone, ranging in size from ½″ to 1″ average diameter. (A thin layer of coarser material is placed at the bottom over the tile, to protect the open joints of the latter against the entrance of obstructing particles.) The sewage, admitted through gates in the distributing main, passes down through the receiving compartment, rising in the smaller or discharging compartment and overflowing into a collecting channel formed in the top of the heavy partition wall. The rate at which it travels is so slow that suspended matters are deposited upon the extended surface of broken stone, forming the filtering medium. This action is purely mechanical, a mere straining out or deposition of the sludge. As these deposits gradually form,

the flow becomes less free, and the level of the sewage rises in the receiving compartment, the increase of head counterbalancing the increased resistance. This condition is accompanied by no deterioration in the quality of the effluent, but, on the contrary, the purification is usually a little better at this stage than when the filter was first started; for the layer of sludge on the surface of the receiving compartment acts as a finer filter, and prevents the passage of even the most minute particles. Eventually a point is reached where with all the head available, the liquid cannot be forced through fast enough to carry off the incoming sewage. The flow is then turned into another strainer of similar construction, where the process of deposition begins anew. There are three of these strainers in all, only one being shown in section. Any two of them, used alternately, are sufficient for regular service, one straining while the other is being cleansed. The third is intended as a reserve in case of emergency; but, in order that it may be always in good working condition, all three strainers are used, one at a time, in rotation.

As soon as a strainer becomes clogged and is thrown out of use, drainage valves are opened and the liquid contents drain away, passing back through a drainage chamber (shown in black) with trapped outlet, to the collecting well for further treatment. (The total amount returned to this well is inconsiderable, for the tanks are drained infrequently and the quantity at each draining is small, being merely that which fills the voids between the broken stone in one of the beds.)

As soon as the water has escaped, air from the blower (which is connected with the drainage chamber, the inlet being shown by the large dotted circle) rushes through the distributing channels underlying the filtering material, and rises through the interstices, supplying speedily to every part the oxygen necessary for bacterial activity. Oxidation at once begins; each particle of filth is attacked by the purifying organisms, disintegrated and resolved into innocuous and inodorous gases or soluble mineral compounds. As an abundant supply of oxygen is maintained, the bacteria multiply rapidly, and in a short time—long before its next period of use comes around—the entire accumulation of filth disappears, and the bed is able to receive and pass sewage as freely as when it was new. This alternate clogging and cleansing proceeds indefinitely. As the accumulated sludge dries and cakes on the surface—usually on the second or third day of æration—it should be broken up, to

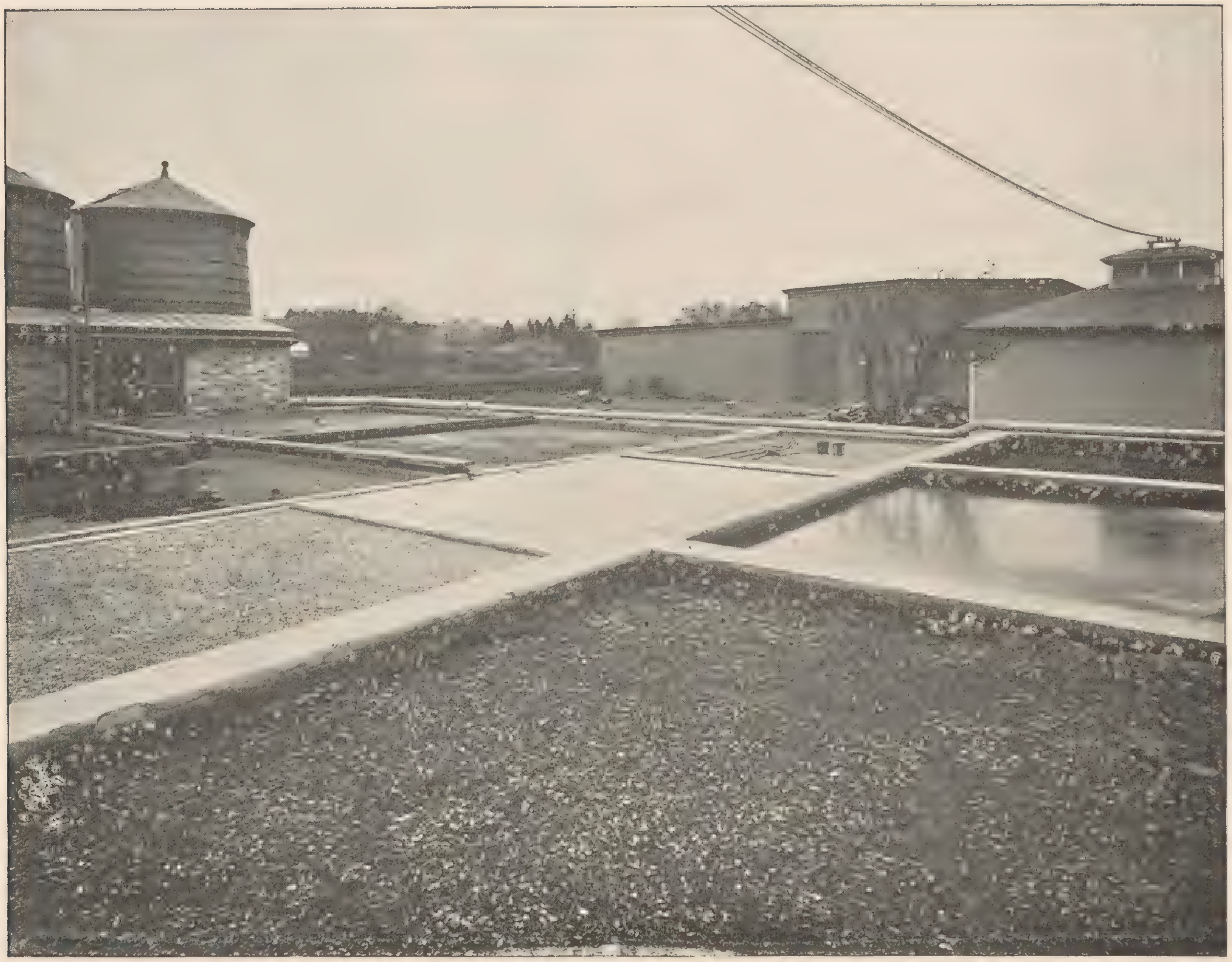

PLATE V.

DESCRIPTION OF PLATE V.

This is a close view taken for the purpose of illustrating as nearly as can be done in a photograph, the operation in actual progress. The middle section of strainers is now receiving sewage and discharging its clarified effluent over the ærating beds in the left middle distance. The further strainers will follow next in order, when those now in action are sufficiently clogged. The strainer in the immediate foreground has been drained about 48 hours. When first drained it was covered with three or four inches of fine gray sludge. This was immediately attacked by the microscopic vegetable (bacterial) growth which in the short time elapsed has very nearly cleared the bed of the whole mass of sludge, without any external aid whatever;—not only the sludge on the surface, but that distributed throughout the entire mass of the bed. Some gray patches are still seen unconsumed in the photograph but in a few hours more these will have vanished and the entire body of stone left as clean as when first taken from the quarry. It is an important point in the paramount economy of the plant that the filtering material never requires renewing or any form of artificial cleansing other than that afforded by the automatic scavenger action of the bacterial growth itself, and which reaches to the remotest interstices of the bed.

faciliate the circulation of the rising air. With proper care, especially in the exclusion of silt, the work of the filter will be uniformly good, and no removal of sludge or renewal of the filtering material will ever be necessary.

As the sewage leaves the strainer, it is free from suspended matter, but is slightly milky or opalescent in appearance. It still contains all the impurities originally in solution. It is collected by a channel, formed in the wall which separates the double strainers from the larger beds, or "ærators." This channel discharges into an iron pipe, which delivers the clarified sewage at the centre of the ærator area, where valves control its distribution through copper gutters in four directions. The function of these ærators is to remove dissolved impurities from the strainer effluent. Drainage and air channels of hollow tiling, which collect the purified water and also distribute air from the blower, cover the floor. Over them, the filling of filtering materials—mainly crushed coke—are placed. The whole is covered with a layer of sand which serves to retard and distribute the flow. The liquid passes through this blanket of sand slowly, and trickles down, in thin films, over the surfaces of the particles of filtering material, finally escaping through a trapped outlet. In its descent it is in constant contact with the current of air, which, introduced at the bottom of the tanks, is continually rising through the voids between the particles and escaping through vent-tiles, which perforate the surface layer of sand, as shown in the Plates.

In the ærators, which work continuously and not alternately, filtration and æration are carried on simultaneously [redacted] The bacteria, which soon establish themselves upon the particles of the filtering material, are in constant activity, being fed by the organic matter in the descending sewage and supplied with air by the ascending blast from the blower. The liquid is subjected to their foraging for about an hour—the period required for its slow percolation through the mass. During this time its dissolved impurities are destroyed, and the only trace of previous contamination left in the effluent is the high percentage of nitrates, which indicates—not innocence, it is true—but complete repentance and regeneration.

The purified water is collected as it leaves the ærators, and carried to an effluent well, which is connected by an underground channel with one of the lakes in the Park, so that the water can be stored for use. It is also pumped, as needed, to the second tank which stands beside the sewage

tank on the roof of the pump-house. Thence it is piped to the various points in the Park and used for sprinkling the roads and lawns, and neighboring residence avenues, flushing water-closets, urinals, etc. It is clean, wholesome water, and, save for sentimental reasons, might well be used in the lavatories, restaurant and drinking fountains.

In all processes of bacterial oxidation, the maximum efficiency is reached only after a certain period of use. The organisms which consume the impurities must be given time to multiply and spread, until their colonies are adapted to the work they are called upon to perform. The plant at Willow Grove first received sewage on May 31st, (1897.) The liquid was clarified immediately by the mechanical removal of suspended matters in the strainer; but its subsequent passage through the ærators caused no perceptible improvement until June 3rd, when the cloudiness and the odor began to diminish. On June 6th the effluent was entirely without odor, but was still slightly opalescent. On June 11th, it was perfectly clear, colorless, odorless and tasteless, and a sample drawn on that day has remained unchanged to this date (February 1st, 1898.) This delay of maximum effect is found only on the first charging of the beds when new, the operation thereafter being continuous. Throughout the entire season the plant has worked smoothly and well, save that on one occasion the strainers became choked with a mixture of clay (which probably entered, with groundwater, through leaks in the sewers) and grease—the accumulation of months in a large grease-trap at the Casino restaurant, which was emptied, with more energy than discretion, by breaking a hole in the protecting trap of the overflow, and sending the entire contents *en masse* into the collecting well. Had this grease been delivered with the sewage, day by day, as made, the filters would have disposed of it without difficulty. The trouble was remedied by forking over the stone and washing it.

The conditions at Willow Grove were, in some respects, peculiarly trying. Not only was the sewage of abnormal strength, as has been explained, but the volume varied enormously from day to day. In a town or city, the domestic wastes remain practically constant in all seasons; but a pleasure park, which is crowded on a hot clear day, will be practically deserted in cold wet weather. The daily attendance at Willow Grove varied from perhaps one hundred to thirty thousand. This caused great irregularity in the operation of the sewage disposal works, and,

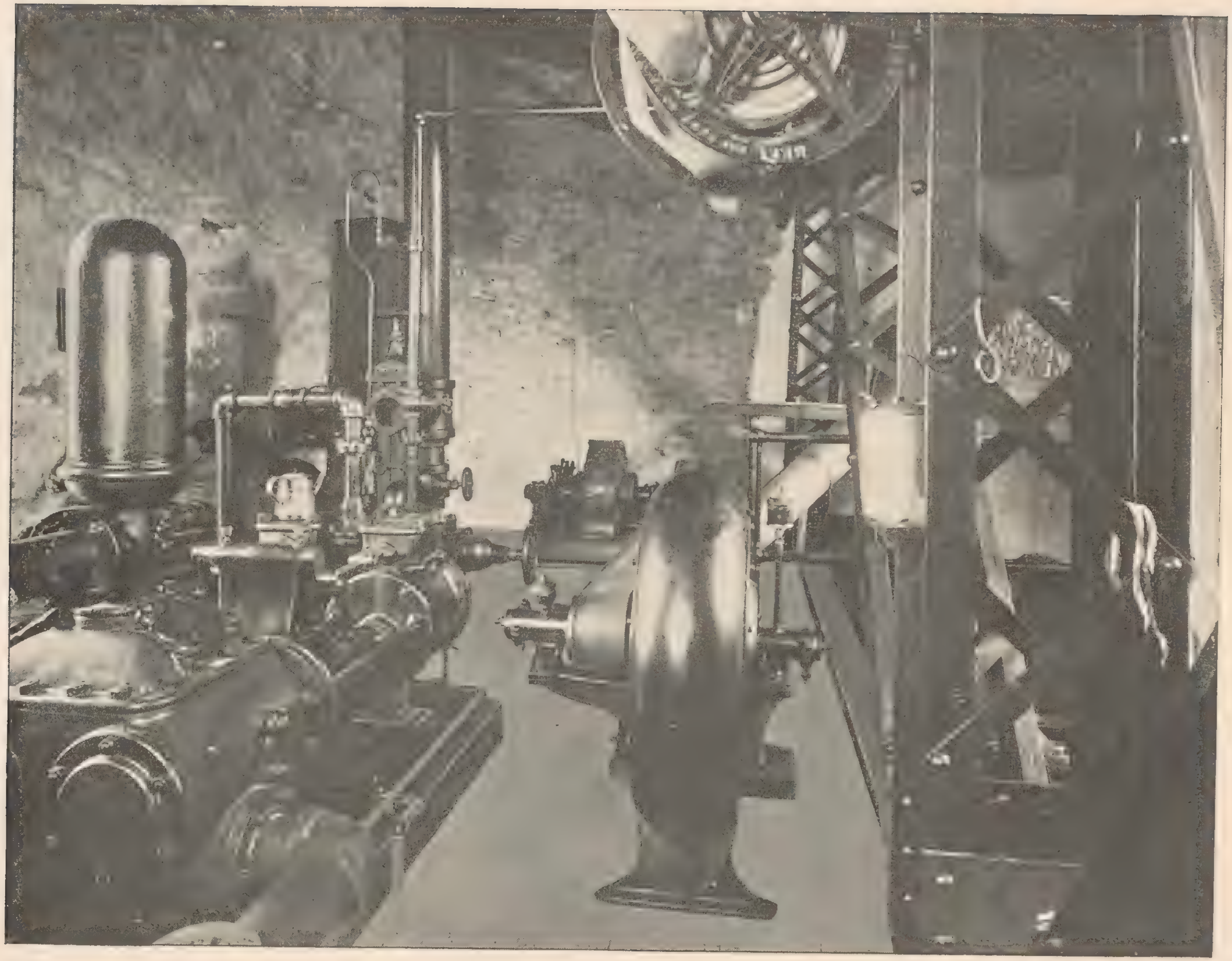

PLATE VI.

DESCRIPTION OF PLATE VI.

The mechanical apparatus for a Sewage Plant is of the simplest nature. In this particular case a steam pump in the left serves equally to lift the crude sewage into Tank No. 1 or the purified sewage into Tank No. 2 when required for sprinkling purposes. Ordinarily, this service is best performed by a centrifugal or rotary pump, but in this instance a steam pump was preferred, owing to the conditions under which the plant was operated.

The fan blower in the foreground, driven by the motor seen beyond it, furnishes a supply of air at low pressure sufficient to permeate the whole bed and stimulate the bacterial growth in every part. This supply of air need not necessarily be continuous but may be intermittent, although the former is on the whole preferable if circumstances reasonably permit.

The iron column work is merely for sustaining the weight of the tanks. These tanks are only necessary when the contour does not permit of a gravity flow or where storage of either the crude or purified sewage is necessary.

under the circumstances, it is somewhat surprising that the result should have proved so uniformly satisfactory.

As has been shown, the process of bacterial oxidation in artificially ærated filters is identical, in theory, with that of irrigation. The difference between them is this that artificial æration supplies to the entire mass of filtering material the conditions necessary for purification, which, in the case of irrigation, are confined to the surface alone. In other words, the introduction of air under pressure makes it possible to concentrate, in cubical form, in a single small bed, the effective area of a whole acre of irrigation field.

The management of the plant is simple, and can be learned easily by an intelligent laborer. It consists mainly in judicious distribution of sewage and air, and the occasional raking over of the filter-beds. One man can care for a large plant. Where sewage can flow to the filters by gravity, the wages of the attendant and the cost of running the fan are the only expenses of maintenance. The filters once built and filled are practically indestructable and self-cleansing.

In respect of cost of operation the method of forced bactereal oxidation allows of no comparison with any other method of sewage disposal, save only the ordinary gravity discharge into river or tide-way, or over irrigation fields.

Sewage Disposal Plants of the same design are now under construction in Brooklyn, L. I., and Tuxedo Park, N. J.

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We estimate, contract for and build—either in a lump sum or on a percentage basis—any Industrial Engineering Construction, to our own plans or to those of other Engineers.

We are by special license, the Contractors for the construction of Sewage Disposal Plants under the patents of Col. Geo. E. Waring, Jr., of New York City and Newport, R. I. The preliminary surveys and the preparation of plans in this particular department are in charge of Waring, Chapman and Farquhar, Civil Engineers, 874 Broadway, New York.

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